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Suite of off-grid options in South Asia

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Abstract

This paper provides a review of alternative off-grid electrification options in South Asia. It covers four elements: the technical dimension, business models, regulatory governance, and sustainability dimension of off-grid solutions. It concludes that in order to go beyond lighting applications, more careful consideration and investigation is required for electricity supply using local distribution networks (or mini-grids), particularly using hybrid technological options.

Keywords: Rural Electrification, South Asia, alternative options

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1.0 Introduction

As part of the research on off-grid electrification in South Asia, our project has investigated the experience of rural electrification around the world and has identified various successful and not-so-successful experiences (e.g. Palit and Chaurey (2011), Bhattacharyya and Ohiare (2012) and Bhattacharyya (2013a). Simultaneously, a significant amount of review work has been carried out to identify the technical options for off-grid electrification, participatory approaches being used for delivery of such services and financial arrangements for supporting off-grid electrification (Kishore et al. (2013), Krithika and Palit (2013), and Bhattacharyya (2013b)). In addition, the project has also looked into the link between rural electrification and economic development (Cook, 2011), the importance of good regulatory governance (Minogue, 2013) and alternative regulatory arrangements (Bhattacharyya and Dow, 2013) for ensuring successful delivery of off-grid electrification for local development.

This paper draws on the above research and provides a summary of alternative suite of off-grid options relevant for South Asia considering the multi-dimensional perspective involving techno-economics, social aspects, environmental issues and governance with a special emphasis on alternative participatory arrangements. In line with the objectives of the research project, we pay greater attention to options that meet the local needs for residential and productive uses. The purpose of this paper is to take a regional perspective in enlisting potential suite of options that could be further investigated through project case studies (but not necessarily through this research project).

The paper is organized as follows: section 2 provides a summary of regional background, section 3 presents the technological options; section 4 summarises the delivery options; section 5 presents the regulatory governance options, section 6 analyses the sustainability of electrification options while section 7 presents concluding remarks.

2.0 Regional background

South Asia consists of eight countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. The region covers an area of 5.13 million square kilometers (or 3.8% of the world area) but holds 24% of the global population (or 1.63 billion in 2010) (World Bank, 2012). The gross national income per person is reported as $1,176, which is about 13% of the world average of just above $9000 in 2010 (World Bank, 2012). However, the countries of the region show significant differences in terms of size, population density and economic development (see table 1): the smallest country, the Maldives, has a very high population density and high income level; two other smaller countries, namely Bhutan and Sri Lanka also have significantly higher per capita income. However, the larger countries of the region dominate in terms of regional population and economic activities – in fact, three countries, namely Bangladesh, India and Pakistan account for 93% of the regional population and 96% of the economic output.

Table 1: Basic information of South Asian countries in 2010

Country	Area, '000 Sq km)	Population, million	Population density (person/Sq. km)	GDP per capita, $	Poverty rate, % of population
Afganistan	652	34.4	52.8	410	36
Bangladesh	144	148.7	1032.6	700	31.5
Bhutan	38	0.7	19.1	1870	23.2
India	3287	1224.6	372.6	1270	37.2
Maldives	0.3	0.3	1053.3	5750	
Nepal	147	30.0	204.1	490	25.2
Pakistan	769	173.6	225.7	1050	22.3
Sri Lanka	66	20.9	316.7	2240	8.9
South Asia	5131	1663.1	324.1	1176	

Source: World Bank (2012).

Although the region has recorded significant economic growth in the recent past, the region still suffers from a high incidence of poverty. More than 500 million (or about one-third of the region’s population) is classified as poor who live on less than $1.25 a day. The region holds the world’s largest concentration of poor people as a result.

Clearly, the high incidence of poverty manifests, among others, in terms of poor electrification rate of the region. More than 493 million people in the region continue to remain without electricity, implying an electrification rate of about 60% on average for the region. There exists wide disparity in rural electrification at the country level however. Sri Lanka has a rural electrification rate higher than the global average while only 15.5 percent of the rural population in Afghanistan is connected to the grid. India, Pakistan and Bangladesh alone constitute more than 90 percent of the population that lack access to electricity in the region while the remaining 10 percent is dispersed in the other smaller countries (see table 2).

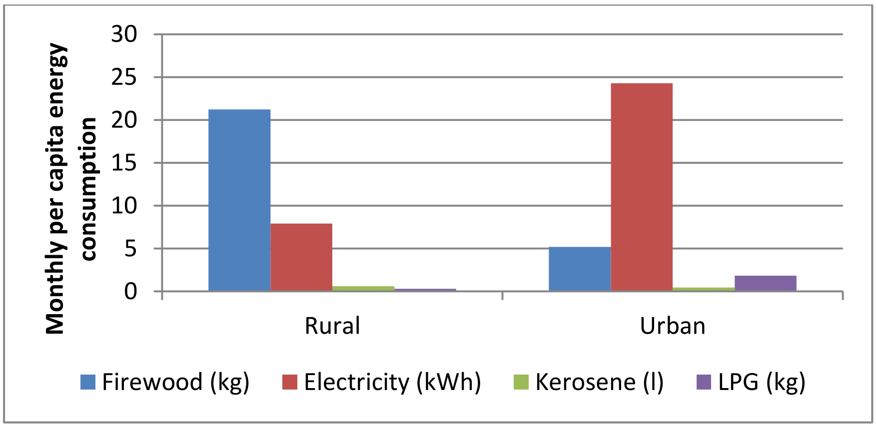
Table 2: Electricity access in 2010 - South Asia

Country	Population without electricity (millions)	Electrification rate (%)		Per capita consumption (kWh)*
		Total	Rural	
Afghanistan	22	30	22	35
Bangladesh	88	47	33	144
India	293	75	67	543
Nepal	7	76	72	81
Pakistan	56	67	55	475
Sri Lanka	5	77	75	418
South Asia	471	70.4	61.3	NA

Source: IEA (2012) and IEA (2009).

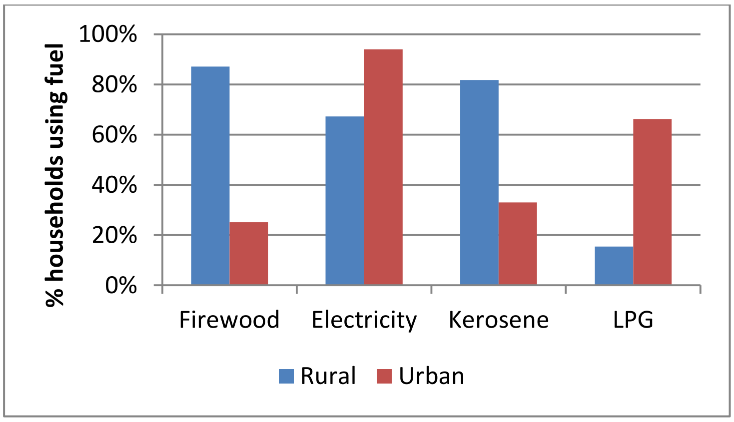
Limited access to clean energies, particularly in rural areas, results in significant differences in rural-urban energy use patterns. A recent survey in India, NSSO (2012), provides a clear picture regarding the differences in the consumption pattern and the fuel mix of energy use by rural and urban consumers in India (see Fig. 1 and 2). While rural consumers still rely heavily on firewood and solid wastes for their energy needs, his urban counterpart relies more on modern energies. The fuel choice reflects the level of access to modern energies as well as consumers' ability to pay for a fuel and related government interventions. Rural households still rely heavily on firewood (87% of rural households use firewood) for cooking with a per capita consumption of about 21 kg of firewood per month while the urban households have moved towards LPG (66% urban households use LPG). The urban consumers are using about 5kg of firewood and 1.8 kg of LPG per person per month. In terms of electricity use, there is a wide disparity as well: 94% of urban households have reported electricity use while 69% of rural households on average consumed electricity, indicating access constraints in rural areas. While an urban consumer has used about 24 kWh per month, a rural consumer has consumed only about 8 kWh per month. Limited affordability of rural consumers and limited ownership of electric appliances as well as supply constraints explain the difference in rural-urban electricity consumption behaviour.

Fig. 1: Disparity in energy use between rural and urban India



Data source: NSSO (2012).

Fig. 2: Share of households using different energies

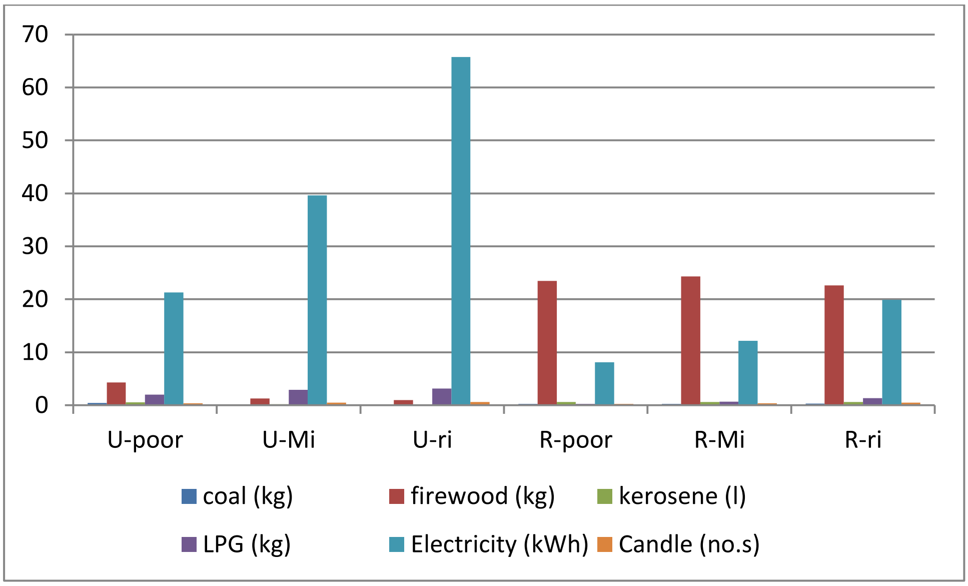


Data source: NSSO (2012).

There is also a significant variation in consumption pattern by income class with urban and rural areas. Based on NSSO (2012) data, a comparative picture is presented in Fig. 3. Although NSSO (2012) provides consumption for each expenditure decile group, for convenience, we have aggregated the information into three categories – rich, medium income and poor – for urban and rural areas. This is based on the following assumption: The 10^{th} decile is considered as the high income group for both areas. For rural poor category, an average of first seven decile classes is considered while for urban poor first six decile classes are considered. The remaining classes are considered as middle income groups. Figure 3 provides very interesting information:

a) Fuel wood remains the main source of energy in rural areas irrespective of income class but this changes completely in the urban areas where fuel wood is only used by the urban poor;
b) LPG remains essentially an urban fuel but the rural rich uses some amount of this product; and
c) Electricity use increases rapidly with income class both in urban and rural areas but the scale is very different in urban areas compared to their rural counter parts. The rich in rural India approximately consume the same amount as the urban poor.

Fig. 3: Fuel consumption pattern by income class in India



Note: U-poor – urban poor, U-Mi – urban middle class, U-ri – urban rich; R-poor – rural poor, R-Mi – rural middle class, R-ri – rural rich.

Source: Based on NSSO (2012).

Although there will be some variation at the country level, similar information is not readily available for other countries. However, it is reasonable to believe that similar patterns are likely to prevail in other countries of the region. Clearly, lack of access to energies affects the development potential of countries in the region as is evident from table 3. Most of the countries of the region have a low Human Development index but those with better energy access have achieved higher HDI and per capita income. This observation is in line with the general trend of other developing countries (see Bhattacharyya, 2012 for a more detailed analysis).

Table 3: Human development indicators for South Asia, 2011

Country	HDI	Life expectancy at birth, years	Mean years of schooling, years
Afghanistan	0.398	48.7	3.3
Bangladesh	0.5	68.9	4.8
Bhutan	0.522	67.2	2.3
India	0.547	65.4	4.4
Maldives	0.661	76.8	5.8
Nepal	0.458	68.8	3.2
Pakistan	0.504	65.4	4.9
Sri Lanka	0.691	73.4	8.2

Source: HDI Database 2011

More importantly, IEA (2012) suggests that the number of people without electricity access in developing Asia will decline in its New Policies Scenario to 335 million in 2030 from 630 million in 2010. But India will remain the most important country with 150 million without electricity access by 2030. This clearly suggests that additional concentrated efforts will be required to ensure universal electricity access by 2030. Given that the possibility of grid extension for universal electrification is limited in the region, the off-grid option is recognized as a feasible option.

3.0 Technologies for off-grid electrification

Decentralised solutions solutions have been promoted where the grid has not reached or is unlikely to reach in the near future. ESMAP (2001) defines them as “an alternative approach to production of electricity and the undertaking and management of electrification project that may be grid connected or not.” Kaundinya et al. (2009) indicate that the extent of decentralization can exist at different levels: 1) village level where the focus is on providing electricity to meet the rural needs, 2) industry level where the demand of the industry is the main focus and any excess power is fed to the grid. Accordingly, the decentralization can lead to grid-connected or off-grid (stand-alone) options. When a decentralized solution is not connected to the grid, it is known as an off-grid solution.

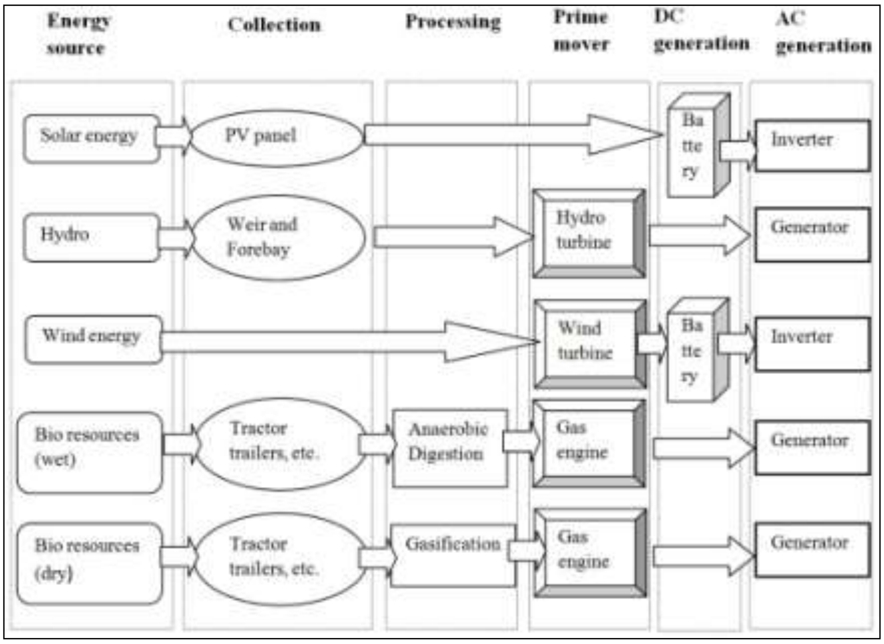
Off-grid systems are mostly used in areas where grid extension is difficult. These systems are demand-driven, small-scale operation for local needs; impose less pressure on resources due to smaller size; are often seasonal in supply due to technological characteristics and need storage systems that incur extra costs (Kaundinya et al., 2009).

Off-grid options can be grouped into two categories – individual solutions and collective solutions. Individual solutions normally include small ready-to-use kit-based systems, such as Solar Home Systems (SHS), solar lamps, and battery-operated systems. IFC (2007) estimates that SHS has provided electricity access to between 0.5 and 1 million households in developing countries. Collective systems come in two modes of operation: stand-alone systems and local-grid systems (ESMAP, 2001). The local-grid systems often rely on diesel generators or hydropower. According to World Bank (2008), portable 5-10 kW diesel generators are widely used as the conventional solutions. However, heavy reliance on diesel for small-scale power generation imposes cost burden on the utilities (more importantly on oil importing countries). The price fluctuations in the international market affect the overall cost of production and the viability of the business. This, in turn, imposes a heavy subsidy burden on the government.

Local-grid system was also developed in hydro-dominated areas. For example, many small hydropower plants in China were initially developed using a local grid system and then connected to the main grid. In the stand-alone category, the solar photovoltaic systems for battery charging systems and charging solar lamps have emerged as a preferred off-grid solution for remote rural areas.

As elaborated in Kishore et al. (2013), a number of energy sources can be used in off-grid applications, including potential energy of water, kinetic energy of wind, heat from solar energy and geothermal sources, and a variety of fuels such as diesel, biodiesel, bio-methane and producer gas (chemical energy). Often a complex chain of processes is required to process the primary energy to deliver the usable form of secondary energy (see Fig. 4).

Fig. 4: Chain of operations involved in off-grid power generation



Source: Kishore et al. (2013).

South Asia enjoys the benefits of both renewable and non-renewable energy resources. For example, the region has significant coal reserves and has some oil and gas resources. But generally, the region is import dependent to meet its fossil fuel needs. On the other hand, there is vast potential for renewable energies in the region. The potential for micro hydro power exists in almost the entire Hindu-Kush Himalayan region, which includes Afghanistan, Pakistan, Nepal, Bhutan, Northern India and Myanmar. Huge potential also exists in several locations in Sri Lanka and Southern India due to their unique geo-climatic conditions (Kishore et al., 2013). Similarly, the average solar radiation incident over the South Asian countries varies from 4 – 7 kWh/day/m2. With most of these countries having about 300 sunny days in a year (Raman et al. 2012), it is but natural for them to explore the possibilities of harnessing the energy of the sun. The region also relies heavily on biomass for its cooking energy needs and being an agrarian economy, there remains some potential for harnessing agro-wastes for energy purposes.

The most common technologies used for off-grid electrification in the region are solar photovoltaic (PV) and mini/micro hydro systems. Solar PV applications in the region include both SHS as well as mini-grids. While a typical SHS includes a 20 to 100 Wp (peak watt) PV array, a rechargeable battery for energy storage, one or more high efficiency lamps (either compact fluorescent or LED) and an outlet for a portable black and white television or other very low power consuming appliances[1], the mini-grids are typically in the range of 2 kWp to150 kWp and provide AC electricity (Palit and Chaurey, 2011). SHS has been the preferred option in many countries of the region for off-grid electrification since late 1980s and the development of LED lights has facilitated a reduction in the size of the systems, which in turn has helped the technology to reach the poorer sections of the population who could not afford the bigger systems even when they were subsidised. However, the main weakness of the technology lies in its limited application potential and its inability to integrate productive uses of electricity directly. Thus SHS is often perceived as a pre-electrification option. In addition, India has also experimented with solar min-grids (both AC and DC versions) in the Sunderbans and in Chhattisgarh.

The mini/micro hydro systems (usually capacity in the range of 50 kW to 3 MW) have been used to create mini-grids to supply AC electricity locally. While Sri Lanka and Nepal have extensively used this technology to extend electrification to off-grid areas, such plants have also been installed in the hilly regions of India such as Arunachal Pradesh, Himachal Pradesh, Sikkim, and Uttarakhand. Many mini/micro hydro projects in the region have been driven by ‘technology push’, with micro-hydro now being a mature technology greatly improved by electronic load controllers, low-cost turbine designs, and the use of plastics in pipe work and penstocks. However, one of the key challenges faced by mini/micro hydro systems especially in India is low utilization factor due to unavailability of sufficient water discharge during dry season and very high discharges during monsoon in the Himalayan streams (when the plant has to be shut down to avoid damage to the penstock or turbine due to possibility of high quantity of silt coming with the water). The low load factors also result in high O&M costs resulting in uneconomical operation in isolated mode in the hilly areas (Palit and Chaurey, 2011).

Biomass gasifiers have found use in India and to a limited extent in Sri Lanka for off-grid electrification. Biomass gasifier based mini-grids are typically in the range of 10 kW to 500 kW. The technology however has found limited success for off-grid electrification. One of the key reasons for this is absence of standardized performance oriented technical specifications of the systems to ensure quality of the products and also due to non- creation

1 Usually SHS with less than 40 Wp is used for lighting purpose whereas SHS above 40Wp can be used for operating other electrical appliances such as TV, motor, fan etc.

of proper after sales maintenance network to service the systems in the remote rural areas[2] (Palit and Chaurey, 2011).

In addition, diesel generators are widely used in the region for own electricity consumption (in homes and for agricultural purposes) but some enterprising villagers also work out an arrangement to provide power either to a cluster of houses or for some economic activity (e.g. village markets). The service depends on diesel availability and is generally a polluting activity but the skills for running such generators are often locally available.

However, there has been very limited experience with hybrid technologies particularly for off-grid applications. In addition, the off-grid services have catered to limited needs by providing electricity for a limited period of time, mainly for lighting purposes in most cases. Thus, a round-the-clock service was not available and the demand growth over time was often difficult to meet.

4. Delivery options

The business model for delivering off-grid electrification tends to vary depending on, among others, the mode of delivery (product sale or local grid-based supply), financing mechanism, and ownership (see Fig. 5). For the stand-alone system delivery, four common delivery options are cash sales by retailers, rental fee-based service by an energy service company (ESCO), leasing arrangements by an ESCO and a micro-finance based scheme. The region has experience with all these options but some of the well-known cases include (See Krithika and Palit, 2013 for more details):

a) Grameen Shakti, a non-profit company, has promoted SHS in Bangladesh through a micro-finance backed system. Following the example of Grameen Bank, Grameen Shakti has created a rural network of decentralized branches all over Bangladesh and has developed a sales strategy linked with consumers' access to finance. Consumers make an initial down payment and repay the rest over a period of time paying a low rate of interest on the loan. By 2012, GS has installed more than 1 million SHS in Bangladesh and recording a 8 fold growth in sales between 2007 and 2012.
b) SELCO, a private social enterprise in India, has used "lease-to-own" approach to promote SHS in South India. Although it does not provide finance to its customers,

2 The performance of the biomass gasifier projects implemented under VESP or RVE program in remote rural areas is found to be unsatisfactory especially due to technology management and product quality issues On the other hand, biomass gasifiers implemented by private companies in some parts of India for electricity supply to 'not so remote' areas are reported to be working satisfactorily.

SELCO supports its customers in securing loans through third-party finances (such as REEEP funding to cover the down payment requirement for securing a loan) and has been successful in installing 135,000 SHS since 1995.

c) TERI's Lighting a Billion Lives campaign that uses a fee-based rental model for promoting solar lighting in India.

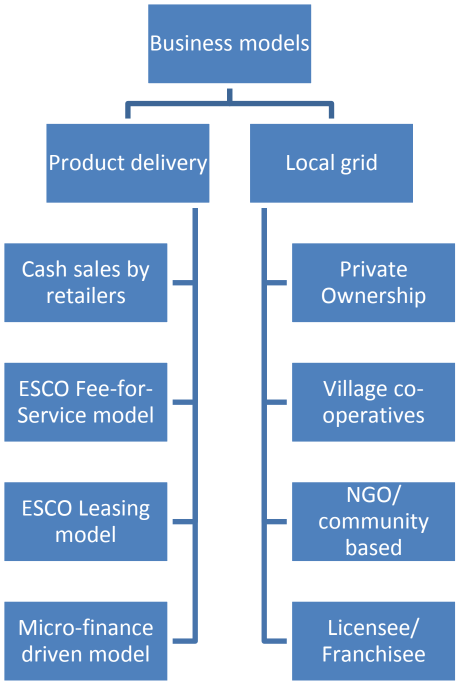
The frequency of transactions involved in the product delivery option can range from a single transaction (cash payment to the dealer and transfer of ownership) to regular interactions over a certain period of time (as in the case of fee for service or lease arrangements). This depends on the nature of the business arrangement chosen (see table 4). However, the duration of the contract tends to be short and long-term dependence of the parties to contract is not common.

Table 4 Nature of transactions in the product delivery option

	Dealer sale-cash	Direct sale – credit	Fee-for-service	Lease arrangement
Frequency of interaction	One	Multiple – regular/ irregular depending on the credit terms.	Multiple – regular transactions	Multiple regular transactions
Contract duration	Instantaneous	Defined by credit terms – normally one to three years	As agreed with the supplier, but with possibility for termination or non-payment	As defined by the lease arrangement, could be terminated due to non-payment
Ownership	Purchaser	Dealer until full payment, then purchaser	Supplier	Supplier
Maintenance responsibility	Purchaser	Purchaser	Supplier	Could be with supplier or user depending on the arrangement

In respect of local-grid based electricity supply in rural areas, the region has experimented with a number of alternative options as well. The private power generation supply through diesel generators has already been mentioned. These use temporary networks and either provide the service for a specific use (fair, market, etc.) or offer the service to a limited cluster of households. These operate on a fully commercial basis and charge usually much higher rates for their supply, commensurate with the small size of their generators (therefore poor technical efficiency) and high cost of diesel fuel used for the supply. In addition to this category of service, renewable energy-based rural electricity supply has also emerged particularly in India, with the Husk Power System being the most well-known case. HPS, a small start-up company based in Bihar, has electrified around 80 villages since 2007, affecting nearly 25,000 households, with plans to expand to 6,500 villages by 2014. HPS builds village scale mini-grids using rice husk gasifiers, usually ranging between 30 and 200 kW systems. HPS works only in locations where at least 250 households agree to take connection and it charges a nominal installation charge as well as a regular fee for electricity, sometimes 45 INR per 15 W CFL. It charges a higher rate for commercial use than for residential use. Some of its plants have generated INR 40,000 monthly revenue from tariffs, considerably greater than average expenses of INR 20-25,000/month (Krithika and Palit, 2013).

Fig. 5: Business models for off-grid electrification



Community-managed systems have been widely used in the region. Micro hydro based developments in Sri Lanka and Nepal, considered to be successful initiatives, are run by the local communities using the locally available water resource to meet their energy needs. On the other hand, India has implemented solar PV-based projects which were successful but the biomass gasifier systems implemented under Village Energy Security Programme (VESP) in India were unsuccessful. Generally, community involvement in a project brings a sense of ownership of the project and hence can enhance the acceptability of the project by the community. But a successful implementation and operation of the system requires appropriate skills, clarity of roles and responsibilities, social cohesion and strong commitment. Lack of technical skills in the community for system operation and financial management often impede with successful delivery of complex electrification projects.

Although the co-operative model has been widely used in Bangladesh, it was used for grid-based electricity supply and not for off-grid electrification as such. In India, the co-operative model has not been widely used but in the case of off-grid electrification in the Sunderbans, this model was used. As members of the co-operative consumers have a sense of ownership of the project and the management tends to take a formal approach than in the case of community-based systems. However, the issue of availability of skills and their retention remains a problem.

The franchisee model has been used in South America to engage private entities in rural electrification. In the case of grid-extension in India, a similar approach was used but this has not been applied in the case of off-grid supply.

A comparative summary of these business models is presented in table 5.

Table 5 - Comparison of alternative off-grid business models

Characteristics	**Energy service delivery model**				
	Cooperative	**Fee-for-service/ ESCO model**	**Community managed**	**Franchisees**	**Private sector**
Ownership	Members of the cooperative own and operate the model	Ownership vests with the ESCO	Can be of two types: • Owned by private/public entity and managed by communities • Owned and managed by communities	Ownership of assets vests with the discom; Franchisee is a custodian of the assets	Owned and operated by the private sector except in PPPs where the ownership of assets may remain with public entity
Management	Managed by a Board of directors or a governing body elected by the consumers	Managed by the ESCO	Managed either by an NGO or local self-governing institutions such as village committees or village councils etc.	Managed by private sector, NGO, SHG etc.	Managed by private sector
Maintenance	Cooperative is responsible for O&M	Maintenance is undertaken by the ESCO	Maintenance is undertaken by the VEC village council etc.	O&M undertaken by the franchise operator	O&M undertaken by the private sector
Pricing	Low upfront cost and monthly tariffs; usually regulated	Low to moderate tariffs (set up by ESCO)	Low to moderate tariffs (mutually decided by the community and VEC)	Moderate electricity tariffs (regulated)	Moderate to high tariffs (set up by service provider)
Community participation	Moderate to high participation. Communities are members of Cooperatives. Local youths may also be involved for bill collection,	Limited participation.	High participation. Communities are involved right from the planning stage till the	Limited participation. Franchisee operators may	Consumers are generally not involved in the planning or

	undertaking minor repairs etc.		end implementation stage. Several functions such as labour contribution for construction, management, maintenance, grievance redressal are performed by communities.	involve locals for bill collection.	management of the business.
Risks	Amenable to political interference.	Communities lack technical and managerial skills and this threatens the sustainability of the model	ESCO carries primary risk of theft. ESCO model is sensitive to uncertainty regarding grid-extension	Franchisee depends fully on discom for power supply and so can't always meet the community's aspiration	Private operator can discriminate by charging high tariffs

Source: Krithika and Palit (2013).

5. Regulatory governance options

Traditionally, when electricity generation and supply has been carried out by a vertically integrated utility, it was a regulated business activity and an electricity act (or a similar legal instrument) generally governed the operational and developmental activities of the industry. Even where the business has been unbundled and deregulated, the transmission and distribution business remains a regulated activity while generation and supply are subjected to lighter supervision and control. Investments in a network facility are largely sunk costs and hardly re-deployable, while the variable cost is relatively low. It is generally considered as a "classic natural monopoly" offering significant scale economies. In such a case one entity can provide the service more economically than multiple entities. The main economic rationale behind the regulation arises from a dilemma involving natural monopoly and the possibility of consumer exploitation by monopolists. The economic logic would then require allowing one entity to provide the service which ensures low cost supply. But if a monopoly is allowed to operate it also has the potential of abusing its power and charge excessive prices for its own profit motives. Forcing the natural monopolist to competition, on the other hand, is likely to lead to a situation of perpetual loss, which would not encourage any private provider to enter the market. The economic regulation tries to balance the dilemma by granting a monopoly status to the service provider but subjecting it to conditions that would protect the consumers as well.

The act normally specifies its area of application and does not generally distinguish between urban and rural areas. Generally the service area of a supply provider includes a mix of urban and rural areas. Therefore, unless a specific exemption or waiver is granted or allowed, the rural electricity supply generally comes under the purview of the general provisions of the act and accordingly, the law of the country essentially decides whether rural electricity supply is a regulated activity or not.

However, the development of decentralized solutions in many countries around the world discussed above requires some attention. The poor state of (or even non-existent) rural electricity supply is a result of the failure of the existing delivery mechanisms. The emergence of the decentralized solutions thus can be viewed as a response to the existing deficiencies that are either arising as a consequence of modifications to regulatory arrangements or perhaps working outside the scope of electricity supply regulations. Two cases mentioned above, namely individual product delivery mode and collective service delivery mode, require specific attention in this respect.

5.1 Regulation of individual solutions

In the case of individual solutions which are delivered through sale or renting of products, electricity supply activity does not take place and hence it does not involve any distribution or transmission networks. The issue of natural monopoly does not arise accordingly. Some amount of electricity generation may take place at the consumer's premises in some of the options (e.g. SHS and mini generators). The law of the land may require consent/ approval for such installations from competent authorities (such as local authorities and even electricity authorities or departments) but being a standard package solution that can be offered by multiple manufacturers, the basic need for economic regulation does not arise.

The responsibility for grid-based electricity distribution remains with the distribution utility but the product delivery mechanism provides a short-term relief until formal supply arrives. As the off-grid product delivery mode does not generally fall under the licensed (or regulated) activity, the electricity regulator does not control such activities. However, once the grid gets extended and the consumer tries to connect her decentralized system to the distribution network, the distribution utility and the electricity regulator becomes interested parties and the activity comes under regulator's jurisdiction.

Although the electricity regulator may not be involved in the product delivery mode, other rules/ standards/regulations may apply to product/ equipment delivery activities. The product or equipment will be subjected to technical standards (regulations) for quality, environmental standards, and even consumer protection regulations/ laws. Similarly, if credit-based systems are used, the financial intermediaries may be subjected to specific financial regulations to prevent cheating, rent seeking and exploitation. Absence or ineffectiveness in any of these governance mechanisms can reduce the benefits to the consumers. On the other hand, the absence of any market at present may justify the need for creating a protective environment for private entrepreneurs, which in turn may require allowing demarcated delivery zones even for product delivery option. This is likely to provide some monopoly rights over the area of delivery but depending on the authority used to grant such a protective environment, the regulatory control would be decided. In general, the competition authority or authority controlling monopoly and restrictive trade practices or a designated state agency would be responsible for monitoring and controlling such issues.

5.2 Regulation of collective solutions

In the case of a collective service provision, the decentralized service is provided as a substitute of grid extension that uses a distribution network and decentralized generators. This conforms to the commonly used definition of electricity supply and hence, unless specifically allowed by the country's law, the business activity will come under the supervision of the electricity regulator. The need for regulation arises for two reasons: 1) to ensure that the activity complies with the law of the land and 2) to protect the investors and the consumers following the standard principles of economic regulation indicated above.

The regulatory arrangement may depend on the mode of delivery chosen in this case and can take different forms.

a) A generic waiver or exemption from the standard provisions applicable to the electricity supplier may constitute a simple solution. This is the approach followed in India where the Electricity Act 2003 allows the state government/ state commission to exempt certain types of organisations from the licence requirements for rural electricity supply either by notifying the rural areas to be covered by them or by the regulator specifying the terms and conditions for such exemption (See Bhattacharyya and Srivastava, 2009 for further details). However, unless the conditions of the waiver or exemption are clearly indicated, and the roles and responsibilities of the parties involved are clearly documented, this simple option can create confusion and may introduce uncertainties for the business. This can also create issues related to reporting and sharing of information related to the activities and may prove to be an ineffective system.
b) A simplified, standardized regulatory approach can be a more practical approach. Such a regulation should specify the role and duties of the provider, set the information filing requirements and ensure consumer protection mechanisms. The purpose of such a light-handed approach is to reduce the cost of regulation by imposing reduced burden on the regulatory agency. This is likely to be effective for local community-based organizations, non-profit organizations and private entities with socially driven motives. For-profit private organizations may try to take advantage of such light-handed systems to increase their profitability. Strong penalties and rule-enforcing mechanisms would be required as deterrents in such cases.

c) A full-fledged regulatory arrangement constitutes the most formal regulatory approach. The existing electricity regulator can be entrusted with these duties or a separate rural electricity (or infrastructure service) regulator can be established. The regulatory powers are normally derived from a specific legislation (such as the Rural Energy Act) and the implementation and governance aspects follow the provisions of such legislation. However, such a regulatory arrangement is likely to be a costlier option and a careful cost-benefit analysis needs to be undertaken prior to the adoption of such an arrangement to ensure that the benefits of regulation would outweigh the costs.

5.3 Regulatory supervision

It is evident from the above that the need for regulatory supervision is not same for two types of delivery channels and for different types of delivery organisations. In the service mode of delivery the regulatory supervision will depend on the ownership of the delivery system. For example, if a distribution franchisee model is chosen the supervision need will perhaps be more extensive whereas in a co-operative model or a community managed delivery system the threat of consumer exploitation may be limited. In general, the regulatory supervision covers the following aspects:

a) Regulated business activities: The service provider is allowed to carry out specific tasks under the permission granted to it. In the off-grid electrification case, it would involve generation of electricity and supply using appropriate infrastructure. The sale of electricity is normally restricted to final users and re-selling is not normally allowed. This would normally require a clear demarcation of the area of activity and a mechanism for avoiding overlaps with the incumbent utility's service area. Absence of clarity in this respect enhances business uncertainties.
b) Activities requiring prior regulatory approval: The service provider is normally subjected conditions requiring it to seek prior approval for a number of activities or transactions. These include sale of the business, engaging agents, or transactions with affiliates, etc.
c) Conditions of supply: Normally a condition of non-discriminatory supply to eligible consumers is imposed to ensure that all consumers meeting the supply criteria are connected. Similarly, any anti-competitive practices or practices leading to market abuse are also not permitted. The regulatory arrangement may provide specific conditions for connection and disconnection.
d) Tariff related provisions: These constitute the most important element of the regulatory supervision. The cost of electricity supply using an off-grid system depends on the technology used, energy resources utilised, size of the system, demand pattern, infrastructure used, service quality and the cost of regulatory compliance. As the cost of supply tends to be high, full cost recovery may lead to limited access (due to limited affordability of consumers) while a limited cost recovery either requires a well-defined subsidy scheme or leads to a unviable business proposition, thereby increasing the potential for underachievement or failure of the system. The tariff issue can be the most contentious issue for the private sector involvement in the business while the challenge is somewhat mitigated in the co-operative or community-based service options.

e) Consumer protection: Protecting the vulnerable consumers constitutes one of the main purposes of regulation. This can cover protection from abusive tariffs, poor supply quality, and other customer grievances (related to billing, connection, disconnection, deposits, technical faults, etc.).
f) Reporting requirements: All regulated entities are required to provide certain information to the regulator to indicate the level of activity, quality of service, or for reporting incidents, disputes or grievances. A systematic flow of information allows the regulator to decide whether to intervene or not and whether any regulatory change is required.

The regulatory requirements for alternative delivery options are indicated in Table 6.

Table 6 Regulatory check for alternative delivery options

Regulatory conditions/ requirements	Franchisee model	Co-operative model	ESCOs	State utility or community based
Electricity sale only for final consumption	Satisfied, as there is no intermediate transaction	Satisfied	Satisfied	Satisfied
Generation of electricity	Required as approved activity	Required as approved activity	Required as approved activity	Required as approved activity
Assignment of transfer of assets/ business permission without prior approval	Required as a condition	Normally does not apply but may be required in case of merger or acquisition	Required as a condition	Normally does not apply.
Engaging affiliates or subsidiaries	Condition required	May arise	May arise	Normally does not arise
Providing loans/ guarantee on obligations	May arise and a suitable condition is required	May arise and a suitable condition is required	May arise and a suitable condition is required	May arise and a suitable condition is required
Undue preference	Suitable condition required	Unlikely to arise	Suitable condition required	Could arise and suitable condition required
Separate accounts for businesses	Required if franchisee operates different businesses	Required if different businesses are undertaken	Required if different businesses are undertaken	Required if different businesses are undertaken
Major incident reporting	Required as a condition	Required as a condition	Required as a condition	May per part of the overall utility reporting scheme
Seeking permission for disposing of or relinquishing assets or control	Required as a condition	Required as a condition	Required as a condition	May be part of the utility's overall regulatory obligation
Demand	Franchisee	Co-operative's	ESCO	Utility

Regulatory conditions/ requirements	Franchisee model	Co-operative model	ESCOs	State utility or community based
forecasting	responsibility	responsibility	responsibility	responsibility
Consumer protection	Franchisee responsibility	Co-operative responsibility	ESCO responsibility	Utility responsibility
System planning	Franchisee responsibility	Co-operative responsibility	ESCO responsibility	Utility responsibility
Tariff regulation	Required to avoid exploitation	Not essential – no profit motive	Required to avoid exploitation	Could be part of overall utility regulation

Evidently, regulation of the business activity will not be an easy process and would require significant amounts of training and capacity building both at the regulatory level and the service provider level.

6. Sustainability of off-grid electrification options

6.1 Methodology

For the sustainability analysis of energy access programmes, an adaptation of a framework suggested by Ilskog (2008) is used. Ilskog (2008) considered five sustainability dimensions – technical, economic, social/ ethical, environmental and institutional sustainability. Each dimension was represented by a number of indicators and each indicator was scored on a scale of 1 to 7. The overall score obtained by simple averaging was used for final ranking of the programmes.

We retain the five sustainability dimensions and identify relevant indicators for each dimension. We then apply this to alternative electrification programmes, namely grid extension, off-grid solar home systems, off-grid electrification through local mini grids, and apply a scoring on a scale of 1 (poorest) and 7 (highest). The score for each indicator was arrived at through a brainstorming session involving a number of energy specialists. We recognise that this is the weakest part of the methodology implementation, which can be improved using a stakeholder survey at a future date.

More specifically, we consider the following (see table 7 also):

a) Technical sustainability is achieved if the system can meet the present and future needs reliably, efficiently and by using clean and renewable sources. This is captured by considering whether the program can satisfy the present and future needs (both residential and productive), whether reliable, efficient and renewable-energy based supply can be delivered and whether supporting services for maintenance and running the systems are locally available or not.

b) Economic sustainability is achieved if the system offers cost effective and affordable supply at present and in the future. This is captured by considering the cost effectiveness and cost recovery potential of supply, capital and operating cost burden imposed on the users, and financial support needs for the system.
c) Social sustainability requires that the solutions should be widely acceptable and accessible to ensure reduction/ removal of human drudgery and adverse effects on women and children.
d) Environmental sustainability aims to reduce the environmental impacts on the users and the society. This is captured by considering contributions to local and global pollution, health damages, and other environmental degradation.
e) Institutional sustainability requires that the provision is locally manageable and controllable. This is represented by the degree of local ownership, availability of skilled staff, ability to protect consumers and investors, and ability to monitor and control the systems.

Table 7 Indicators of sustainability of energy access programmes

Technical sustainability	Economic sustainability	Social/ ethical sustainability	Environmental sustainability	Institutional sustainability
Ability to meet present and future domestic needs	Cost effectiveness	Wider usability amongst the poor	Contribution to reductions in carbon emissions	Degree of local ownership
Ability to meet present and future productive needs	Cost recovery potential	Need for micro-credit or financial support systems	Contribution to reduction in indoor pollution	Need for skilled staff
Reliability of supply	Capital cost burden on the user	Potential to reduce human drudgery	Contribution to reduction land degradation	Ability to protect consumers
Reliance on clean energy sources	Running cost burden on the user	Potential to reduce effects on women and children	Contribution to reduction in water pollution	Ability to protect investors

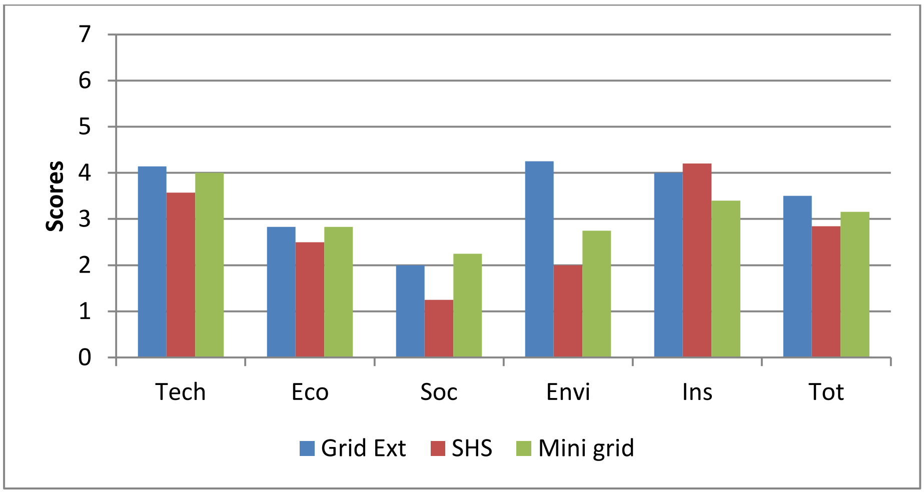
Technical efficiency	Financial support needs			Ability to monitor systems
Reliance on local resources	Contribution to income generating opportunities			
Availability of support services				

While it is possible to include more factors in the sustainability analysis, the above provides a reasonable picture of the multi-dimensionality of the challenge. Although a more formal framework using multi-criteria decision-making approach is also possible, the above provides a good starting point.

6.2 Analysis of the results

The result of the analysis is presented in Fig. 6. Grid extension emerges as the preferred alternative for lighting option, although it received just about 50% of the possible scores. This suggests its weakness as an all-round solution. The SHS received the weakest score of all because of its limited ability to meet the needs. However, no option reaches the highest score of 7 in the overall assessment, indicating their weakness in certain areas.

Fig. 6 Sustainability comparison of alternative electricity access programmes



Source: Bhattacharyya (2012).

The scores related to the economic sustainability are relatively low, reflecting the problem of sustaining such solutions without some support mechanisms. Local resources fare better in this respect but cost issue remains a main problem in all options. Moreover, some sustainability issues exist for each dimension. The inability to meet future demand, particularly productive needs, and poor technical efficiency and reliability of the systems are serious technical constraints faced by most of the access options considered in this exercise. The inability of lighting-oriented access options to reduce drudgery and to promote wider clean energy use amongst the poor affects the social sustainability of such options. The lighting options also score relatively low in terms of environmental benefits as these options miss the most important energy needs of the people.

The above analysis suggests that the existing practices of providing electricity access are generally unsustainable from a number of perspectives although this has received limited attention. Over-emphasis on limited-impact options needs to be avoided and a rebalancing of provision options is required to ensure a more sustainable approach to resolve the problem. Hybrid options are likely to perform better in this respect, although our analysis did not focus on these solutions. Also, further analysis of country-specific experiences is required to identify sustainability challenges in specific cases.

7. Conclusion

One of the main challenges of our time is to ensure universal access to energy but IEA (2012) indicates that unless concerted efforts are directed to address the challenge, South Asia will remain a problem area even by 2030. As grid extension is unlikely to materialise in the entire region, off-grid options will play an important role. Although the region has gained some experience in off-grid electrification over the years, the focus has been mostly on solar home systems but given its limitations in terms of service SHS can only be considered as a pre-electrification or a temporary solution until grid comes. Moreover, the initial investment being significantly high relative to the ability to pay by the poor, this option has hardly reached the poorest section of the population, even where micro-finance has been organised. Thus a step change is required where the local supply will include productive use of electricity that can positively catalyse the economic development at the local level.

The local grid-based systems thus require more attention. Although the region has experimented with this option as well, particularly using micro-hydro technologies, solar PV and agricultural wastes (e.g. rice husk), the result remains mixed. While a properly designed and operated micro-hydro system can provide the cheapest electricity, the reliability of supply can be a major challenge due to seasonal water availability, poor maintenance and lack of local skills in managing the system. Similarly, although there is now a reasonably long-lasting experience of dealing with solar PV-based mini-grids in the region, long term issues such as meeting demand in the future, ensuring a reliable and cost-effective supply and supporting productive uses for rural development remain. Further, there is very limited experience with hybrid systems and clearly, there is a significant vacuum in the regulatory sphere.

The suite of technological options, business models, regulatory and governance options enlisted in this paper can be provide useful information for developing further research particularly using hybrid options for promoting reliable and cost-effective solutions at the local level.

References

Bhattacharyya, SC (ed.), 2013a, Rural Electrification Through Decentralised Off-grid Systems in Developing Countries, Springer, London.

Bhattacharyya, SC and L Srivastava, 2009, Emerging regulatory challenges facing the Indian rural electrification programme, Energy Policy, 37(1):68-79.

Bhattacharyya, SC and SR Dow, 2013, Regulatory issues related to off-grid electricity access, Chapter 11, in SC Bhattacharyya (ed.), Rural Electrification Through Decentralised Off-grid Systems in Developing Countries, Springer, London.

Bhattacharyya, SC, 2012, Energy access programmes and sustainable development: A critical review and analysis, Energy for Sustainable Development, 16(3): 260-71.

Bhattacharyya, SC, 2013b, Financing energy access and off-grid electrification: A review of status, options and challenges, Renewable and Sustainable Energy Reviews, 20:462-72.

Bhattacharyya, SC, and S. Ohiare, 2012, The Chinese Electricity Access Model for rural electrification: Approach, experience and lessons, Energy Policy, 49: 676-87.

Cook, P., 2011, Infrastructure, rural electrification and development, Energy for Sustainable Development, 15(3): 304-13.

ESMAP, 2001, Best Practice Manual: Promoting decentralized electrification investment, World Bank, Washington D.C.

IEA, 2009, World Energy Outlook 2009, International Energy Agency, Paris.

IEA, 2012, World Energy Outlook, 2012 Electricity Access Database, International Energy Agency, Paris.

IFC, 2007, Selling solar: Lessons from more than a decade of IFC's experience, International Finance Corporation, Washington D.C. (see http://www.ifc.org/ifcext/sustainability.nsf/Content/Publications_LOE_SellingSolar).

Ilskog, E., 2008, Indicators for assessment of rural electrification – an approach for comparison apples and pears, Energy Policy, 36, pp. 2665-73.

Kaundinya, D. P., P. Balachandra, and N.H. Ravindranath, 2009, Grid-connected versus stand-along energy systems for decentralized power – A review of literature, Renewable and Sustainable Energy Reviews, 13, pp. 2041-50.

Kishore, VVN, J. Dattakiran and E. Nand Gopal, 2013, Technology Choices for off-grid Electrification, Chapter 3, in SC Bhattacharyya (ed.) Rural Electrification through Decentralised Off-grid Systems in Developing Countries, Springer, London.

Krithika, PR and D. Palit, 2013, Participatory Business Models for Off-grid Electrification, Chapter 8, in SC Bhattacharyya (ed.) Rural Electrification through Decentralised Off-grid Systems in Developing Countries, Springer, London.

Minogue, M., 2013, Regulatory governance of off-grid electrification, Chapter 10, in SC Bhattacharyya (ed.), Rural Electrification Through Decentralised Off-grid Systems in Developing Countries, Springer, London.

NSSO, 2012, Household consumption of various goods and services in India, NSS 66th round, National Sample Survey Office, National Statistical Organisation, Government of India, New Delhi.

Palit D, Chaurey, A., 2011, Off-grid rural electrification experiences from South Asia: Status and best practices. Energy for Sustainable Development 15; 266–276

Raman P., J Murali, D. Sakthivadivel and VS Vigneswaran, 2012, Opportunities and challenges in setting up solar photo voltaic based micro grids for electrification in rural areas of India. Renewable and Sustainable Energy Review (16): 3320-3325

World Bank, 2008, 'The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits', An IEG Impact Evaluation, Washington DC, World Bank.

World Bank, 2012, The Little Data Book, 2012, The World Bank, Washington D.C.

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Disclaimer

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OASYS South Asia project

The Off-grid Access Systems for South Asia (or OASYS South Asia) is a research project funded by the Engineering and Physical Sciences Research Council of UK and the Department for International Development, UK. This research is investigating off-grid electrification in South Asia from a multi-dimensional perspective, considering techno-economic, governance, socio-political and environmental dimensions. A consortium of universities and research institutes led by De Montfort University (originally by University of Dundee until end of August 2012) is carrying out this research. The partner teams include Edinburgh Napier University, University of Manchester, the Energy and Resources Institute (TERI) and TERI University (India).

The project has carried out a detailed review of status of off-grid electrification in the region and around the world. It has also considered the financial challenges, participatory models and governance issues. Based on these, an edited book titled "Rural Electrification through Decentralised Off-grid Systems in Developing Countries" was published in 2013 (Springer-Verlag, UK). As opposed to individual systems for off-grid electrification, such as solar home systems, the research under this project is focusing on enabling income generating activities through electrification and accordingly, investing decentralised mini-grids as a solution. Various local level solutions for the region have been looked into, including husk-based power, micro-hydro, solar PV-based mini-grids and hybrid systems. The project is also carrying out demonstration projects using alternative business models (community-based, private led and local government led) and technologies to develop a better understanding of the challenges. It is also looking at replication and scale-up challenges and options and will provide policy recommendations based on the research.

More details about the project and its outputs can be obtained from www.oasyssouthasia.dmu.ac.uk or by contacting the principal investigator Prof. Subhes Bhattacharyya (subhesb@dmu.ac.uk).

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